PETROLOGY AND PROPERTIES OF CERTAIN CLAYS FROM QUEENSLAND, AUSTRALIA

BY

JOHN ALEXANDER FERGUSON

B.Sc., University of Queensland, 1946

M.Sc., University of Queensland 1948

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN GEOLOGY IN THE GRADUATE COLLEGE OF THE UNIVERSITY OF ILLINOIS, 1950

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GENERAL INTRODUCTION

These investigations are concerned with two aspects of the clay deposits of south east Queensland (1) the Mesozoic, Tertiary and Recent clays and shales used industrially in the Brisbane Ipswich area, and (2) the types of soils formed from the Tertiary basalt lavas, the area most intensely studied being the Main Range at Toowoomba.

The purpose of these studies is to secure fundamental information on the clay mineralogy and physical properties of these shales and soils, and thus to evaluate the origin, history and relationships of the various types, and to arrive at an understanding of practices employed in their utilisation, present and future.

(A) INDUSTRIAL CLAYS OF THE BRISBANE IPSWICH AREA

In the Brisbane Ipswich area, the Bunya Phyllites, Ipswich Coal Measures, Redbank Plains Formation, and Recent stream alluvia are now being used as sources of ceramic raw materials. Additional supplies could be won from the Esk Formation (in part), Bundamba Sandstones, Brighton Beds and Petrie Formation.

The Bunya Phyllites are tough and costly to quarry, and only a partly diaggregated zone of weathering is used. In the Mesozoic Coal Measure sequences, both arenaceous and argillaceous types can predominate in sections up to 100 feet thick, each with narrow intercalations of the other type, but usually members are 2 to 10 feet thick, relatively uniform in themselves, and change abruptly to another lithological type of similar uniformity. Laterally beds have gentle undulations and thicken and thin irregularly over very small distances. Such a section often contains a variety of clay material that can be won bed by bed and adapted for specialised ceramic uses. Weathering zones above these are often used, for they are white, open and homogeneous in texture, more plastic than the parent shales, and often rather deep. Tertiary and alluvial clays used are richer in iron, very plastic and sticky.

Forty of these clays and shales were collected to represent

natural subdivisions of material now being used ceramically. To evaluate their fundamental properties and relate these to present and future utilisation practices, appropriate ones were investigated by optical, X-ray diffraction and differential thermal analyses, and determinations were made of particle size, drying and firing character, fusion point and bonding strength capabilities.

Mineralogically there are two main groups of clays: (a) essentially quartz kaolinite clays (largely confined to the Mesozoic Coal Measures), and (b) those with considerable montmorillonite content, stemming from partially dissociated mixed layer associations of montmorillonite and mica like minerals. These latter are best represented in Tertiary and Recent deposits. Members of the first group (a) are moderately plastic, medium to low in shrinkage, light burning and moderately refractory; members of the second group (b), are high in plasticity and original water content, are slow drying with large shrinkage, often cracking and distorting, red burning and non-refractory. Several kaolinites show varying degrees of lattice imperfection due to the partly random superposition of successive layers with respect to one crystallographic axis, a property modifying their refractoriness to some extent. Mixed layer associations were probably developed during the metamorphism of the Bunya Phyllites, when they were held together in a non-expanding lattice, devoid of water holding, plastic and thermal properties. During weathering—as in the post-palaeozoic sedimentation—a reversal to clay like minerals, and especially release of montmorillonite takes place. X-ray patterns indicate mixed layer minerals by a diffuse line, or better, band, about 10.8Å, intermediate between the position of the two constituents; after further weathering it fans out over the range 10.8Å - 14.5Å, then both sides of this may be intensified, and with very advanced weathering, the inner 14.5Å montmorillonite line dominates. Optically these minerals resemble illites at all stages of weathering. Thermal curves show the inert ancestor developing a shallow depression at 120°C. as basal interlattice surfaces are unlocked for water adsorption; later the characteristic montmorillonite curve is apparent, with a dual initial peak.

Montmorillonite bearing clays show a large fraction below 0.5 microns; amongst quartz kaolinite clays, there is often a significant increase in the amount of this small particle size in the upper weathering zones. The amount of this fraction closely controls the amount of tempering water, and the drying shrinkage. Several

of the kaolinite clays from lower soil zones contain no iron and burn white. This is true also of carbonaceous shales, which lose all their carbon without blistering or disruption. A number, especially from upper soil zones, fired faint cream or pink. Both these types had minimum shrinkage. The remainder, mainly clays with significant amounts of mixed layer minerals, burned red with larger shrinkage, but retained their shape well if a quantity of non-plastic material was present. Kaolinites with well organised lattices are more refractory than those with poorly organised ones, unweathered kaolinite shales more refractory than weathered, and kaolinites much more so than clays with mixed layed minerals, which frequently bloat. Mixed layer mineral clays are best for bonding purposes.

Economic and geological control indicates five main areas of location of structural clay industries about Brisbane and Ipswich; (1) between the two cities, near both coal and markets; on the margin of the metropolitan market at (2) Virginia-Strathpine, (3) Cannon Hill-Hemmant and (4) Sunnybank-Coopers Plains, each with adequate clay materials; and possibly (5) north of Ipswich to supply that more limited market. Other new and expanded uses for these raw materials are fine china, electrical insulators and high grade ceramic wares for the white burning low shrinkage kaolinites; well glazed pottery, floor tile, sanitary ware and stoneware for the slightly red burning ones; medium duty refractories from many kaolinites, especially those with good lattices; ball clays, rubber fillers and possibly catalysts from a unique white burning montmorillonite; paper fillers from white kaolinites; red pottery wares, flower pots and wall tiles from red burning clays which retain their shape; bonding clays from montmorillonite bearing Tertiary clays and recent alluvial and phyllite soils; and expanded aggregate from high iron montmorillonite clays.

(B) CLAY MINERALOGY AND GENETIC TRANSFORMATIONS IN BLACK EARTHS AND RED LOAMS OF BASALTIC ORIGIN.

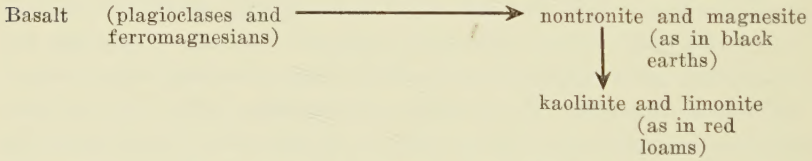
In south east Queensland and northern New South Wales, two distinctive soils are produced from basalt—the black earths and the red loams. The association of these two and intermediate forms occurs here in definite relation to topography—the red soils at the top of high eastern scarps, intermediate soils beyond them, and black earths still further out on the flat western plains, as well as on the steep eastern fall.

A systematic collection of samples of such a soil association from the Toowoomba area in Queensland has been investigated by X-ray diffraction and differential thermal analysis to evaluate clay mineral composition and variation within the soils.

Nearly all the soils contain montmorillonite, including the red ones, except one which has undergone intense lateritsation. It is suggested that montmorillonite is the first formed clay mineral when basalt weathers under present conditions.

Going from east to west the sequence seems to be: (a) montmorillonite and high organic matter (in dark soils on the steep eastern slopes); (b) montmorillonite, kaolinite and limonite (red soils at top of range); (c) kaolinite and limonite (at top of range only); (d) kaolinite, increasing montmorillonite and organic matter (intermediate dark red, brown and chestnut soils); (e) montmorillonite, carbonate and high organic content (black earths, in situ and alluvial).

Under certain restricted more humid conditions now or in the past, the progressive change from black to red soils occurs, accompanied by gradual decomposition of montmorillonite. The weathering scheme is thus as follows:


Basalt
(plagioclases and ferromagnesians)
nontronite and magnesite (as in black earths)
kaolinite and limonite (as in red loams)

The secondary change to red soils was far more extensive in the past, when it reached lateritic proportions, but may still be active in the production or at least sustenance of red loams in localised areas of consistently humid atmospheres bearing little relationship to the yearly rainfall. They exist (a) where scarps obstruct the valley circulation of prevailing moisture bearing winds, so becoming prone to fogs and showers; (b) right at the sea coast; (c) where rain forests ensure humid soil atmospheres. In this way a minimum of atmospheric moisture is retained in prolonged contact with the upper zone of soil material. Where these situations impinge on flat lying areas of weathered basalt, the maximum influent seepage occurs, and sluggish downward percolation of groundwater allows a long time for leaching and oxidation. As a deep profile is

produced, and as more permeable kaolinite forms, the change from montmorillonite is accelerated.

Partial reversal to darker soils, in soil-in-soil profiles, is due to instability of limonite in the present podsol forming climate, and the ascendency of montmorillonite still present in the red loams, rather than the synthesis of montmorillonite anew. As the removal of clogging limonite gives montmorillonite freer rein in restricting soil permeability, and as reduced moisture due to drier climate curtails leaching, favourable conditions are set up for the reinstatement of organic matter, some of it adsorbed on the montmorillonite itself.

Apart from the specially intense degradation to red soils, basalt weathers typically to black montmorillonite bearing soils, as on the Darling Downs, in extensive basalt alluvia, and in many of the small areas of basalt in the lowlands of south east Queensland. On steep range slopes and on plateau areas in rain shadows, leaching and aeration are sufficient to restrict the accumulation of organic matter, but not enough to cause destruction of the montmorillonite, so grey montmorillonite bearing soils result. However, a partial transition to brown and chestnut soils occurs commonly where leaching is increased as by higher rainfall.

VITA

John Alexander Ferguson was born on October 12, 1925 at Gympie, Australia. After his earlier academic training at Cooran State School, Gympie High School and University of Queensland, the latter granted him the degree of Bachelor of Science in 1946; in 1947 he qualified for the degree of Bachelor of Science with First Class Honours, and was admitted to the degree of Master of Science in 1948. For two and a half years, beginning in 1946, he was engaged also in geological investigations for the Coordinator General of Public Works of the State of Queensland, which included: surveys of underground water supplies, especially in the Great Artesian System; geological work on potential irrigation, dam site, soldier settlement and general land utilisation projects; and investigation of the clay industries of the state. The award of an Overseas Studentship by the Australian Council for Scientific and Industrial Research allowed him to undertake two years of study and research in the Graduate College, University of Illinois during the academic years 1948-49 and 1949-50.